REPRINTS

# INDIAN TEA ASSOCIATION

## TOCKLAI EXPERIMENTAL STATION

*MEMORANDUM NO. 14*

# RED RUST

*BY*

*A. C. TUNSTALL*

IMPERIAL MYCOLOGICAL INSTITUTE
27 MAY 1942

*Dated 15th January, 1942.*

# Indian Tea Association

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Plate (1) — Red Rust *(Cephaleuros parasiticus)* on tea. (1) Orange coloured fruiting patches on young stems. (2) Old patches forming cracks on the bark. (3) Variegated leaves.

# INTRODUCTORY

The definite recognition of Red Rust as a tea blight dates back to 1890, when it was found on tea twigs from Nowgong, Assam, and described by Dr. Cunningham. In 1895 Dr. Watt showed that the blight was very widespread and in his report in 1898 he suggested that it was likely to become a serious menace to the industry. The great importance of the blight was generally recognised in 1900 and in 1901 Mann enquired into its nature and published a paper on it. In 1904 a revised edition of this paper was written by Mann and Hutchinson. This was the last comprehensive discussion on the disease to be published by the Indian Tea Association.

The writer has very clear recollections of seeing, 25-30 years ago, considerable areas of mature tea reduced at the end of the growing season to thin bare sticks surmounted by a few sickly-looking, stunted shoots. This condition had been induced by severe attacks of Red Rust. Losses of from 10-15 per cent of crop were not infrequent on old tea. By that time however it was generally recognised that bad drainage was particularly responsible for susceptibility to such severe attacks.

Increasing knowledge of the requirements of the tea plant and the consequent improvement in cultural operations have in more recent years rendered the tea in North-East India so much less susceptible to such attacks that specific treatment was no longer necessary. Many planters now-a-days would fail to recognise the effects of Red Rust. Since the introduction of restriction however large areas of impoverished soil, often in poor physical condition, have been replanted and on such soils the young tea plants are frequently damaged by this blight. Even in good soils damage of young plants sometimes occurs whenever climatic conditions are unfavourable. It is therefore considered advisable to publish a description of Red Rust and its treatment.

## DESCRIPTION OF THE BLIGHT ON TEA

In the early part of the growing season on any section of tea in North-East India a few twigs may be found with orange-red patches on the brown bark. If these patches are examined with a lens it will be found that they are collections of orange-red hairs surmounted by clusters of knobs. These are the fruits of an alga called **Cephaleuros parasiticus** which is exceedingly common throughout the tropics. These fruits are so small that they are barely visible to the naked eye. It should be noted that a common harmless fungus called **Stilbum nanum** bears fruits with a superficial resemblance to those of Red Rust. They are however very much larger. Closer examination of the orange-red patches will show that the bark beneath them appears to be unhealthy. Its surface is often cracked longitudinally and covered with flakes of dried up bark. Some of the twigs bearing these patches will be found to be dead but most of them will have one or two sickly, stunted leaves at their ends while all the other leaves have fallen off. Sometimes the leaves remaining on the rusted branches become variegated with yellow streaks and patches. This does not always occur nor is such variegation always the result of Red Rust attack.

The orange-red fruits are only found in quantity during May, June and July ; at other times of the year the patches caused by Red Rust are not so easily identified.

## THE BLIGHT ON THE LEAVES

Parasitic Form.—Circular patches of the characteristic orange-red fructifications may be found on mature leaves at any time of the year though they are more prevalent in May, June and July. These patches are of two kinds. The commonest kind is on a circular piece of discoloured tissue which extends right through the leaf. Most of the fruits are on the upper surface but a few also form on the under one. The patches are usually surrounded by a purplish ring of semi-translucent appearance. This ring is not always present. Some semi-translucent purplish patches may also be observed without any of the orange-red fruits. These are usually very small and are the early stages of the infection. It should be noted that when tea leaves are about to fall oily spots often develop which have no connection with Red Rust.

Plate (2) — Red Rust *(Cephaleuros parasiticus)* on tea leaves.

Epiphytic Form.—Another type of orange-red patch may also be found on the upper surface only of mature leaves. These do not extend through the tissues to the lower surfaces. In some cases the patch may be scraped off leaving the epidermis apparently unaffected. In its earlier stages this form of the alga appears on the leaf surface as a small greenish coloured disc. This becomes red later. This is the epiphytic form and is called **Cephaleuros mycoidea,** Karst.

## APPEARANCE ON GREEN BARK

The alga does not damage the green bark of branches so readily as the brown bark. On green bark the alga causes small oily spots of a purplish tint. On mature tea bushes severely attacked by Red Rust the young branches are unusually thin and the leaves sparse. At the end of the growing season the general appearance of the tops of the bushes is thin and brushlike.

## CALLOSITIES ON YOUNG BRANCHES

Sometimes the centre of the spots dies and later in the season a cushion of callus forms at each spot. This callus goes on growing and the young branch becomes a mass of callosities. This condition does not occur frequently and seems to be the result of temporarily adverse conditions of growth on tea which normally grows very vigorously.

## ABNORMAL HARDENING OF THE GREEN BARK

One of the characteristics of Red Rust attacks on green shoots is the abnormally early production of the permanent bark. Occasionally an infected twig which would normally have green bark will be found to have produced secondary bark almost up to the terminal bud. This is probably due to the premature drying up of the primary cortex on account of the formation of a layer of algal cells just beneath it.

## APPEARANCE ON ONE YEAR OLD WOOD

The alga is most commonly found on the brown bark. The strips of dead primary cortex afford excellent resting places for the development of the alga. In most cases the alga does little more than infect these dead strips or at most the outer layers of cells of

the secondary bark. On weak branches the alga forms plates of cells beneath successive layers of bark cells. The layers of the cells cut off from water supply by the algal elements crack and flake off. This causes a slightly raised area of darker colour and usually covered with longitudinal cracks. The branch may be completely ringed in this way but more often the patch of diseased tissue is only on one side. The flaking off process may continue until the wood is exposed. When the layers of algal cells are deep seated in the tissues they absorb much of the water supply required by the portions of the branch above them, buds cease to grow and leaves fall off.

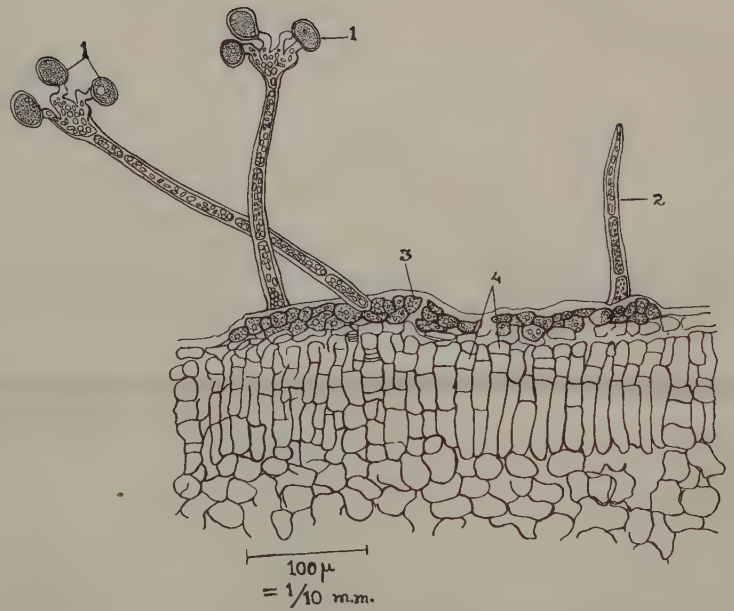
## APPEARANCE ON OLD WOOD

On tea plants Red Rust is not commonly found on wood older than three years. Where it occurs it causes a somewhat raised patch without any characteristic change of colour. It is covered with fine longitudinal cracks and tiny flakes of dead bark. On trees with thick bark such as leguminous trees it sometimes causes lesions of considerable size with large pieces of dead bark of dark colour.

## BLIGHT ON OTHER PLANTS

The same alga is very common on the bark of jungle plants which it occasionally parasitises. It is frequently seen in the parasitic form on the older stems of Boga medeloa **(Tephrosia candida)**. On one year old branches of shade trees such as **Albizzia stipulata** it forms characteristic patches which are readily seen. On green bark the alga causes some irregular swelling ; sometimes the swollen portions have a starfish shape. The edge of the spot at this stage almost invariably looks oily and has a purplish tint. It is not uncommon on weaker branches growing on healthy looking trees but it is more usual to find it on trees which lack vigour. These patches are similar to those on tea branches but are larger. The blight remains on the branches year after year. As the bark of these plants is much thicker than that of tea it is possible to observe the scaling of layer after layer of bark killed by the alga. This scaling process goes on until the wood is exposed and lesions similar to those caused by severe hail-damage sometimes result. In time the exposed wood becomes infected by fungi and the whole branch is not infrequently lost.

Plate (3) — Red Rust *(Cephaleuros parasiticus)* on Boga medeloa *(Tephrosia candida)*. (1) On young stem. (2) and (3) On old stems.




Section of a tea leaf bearing an algal disc on its upper surface. 1. Sporangia of the Red Rust alga. 2. Sterile hair. 3. Cells of the algal disc. 4. Palisade cells of the tea leaf showing abnormal cross walls immediately below the algal disc.

## THE LIFE HISTORY OF THE PARASITE

The orange-red heads of the fructification contain large numbers of spores. These spores are provided with two tails which arise from the same point. By means of these tails the spores can move about in water. They are very small but in spite of this they are capable of surviving desiccation for a considerable time. They are readily carried about by the wind. There is never any lack of infecting material and the conditions under which the spores may survive are not of any practical importance.

## GERMINATION

During the rainy season the conditions for the germination of the spores are ideal. The surfaces of the host plants are covered with a film of moisture in which the spores are free to move. In spite of the enormous numbers the majority of spores produced fail to produce an adult plant. On germination the spore produces a small greenish coloured disc of algal cells. The cells contain chlorophyll and are capable of collecting the energy they need direct from the light like any other green plant. Most of the algal discs continue an independent existence. Many of these discs may be found growing on inanimate substrata such as stones, clods of earth, etc., etc.

## PENETRATION OF PLANT TISSUES

When a disc is situated on the epidermis of a living plant some of the algal cells in contact with the epidermal cells grow between them and actually penetrate some of them. This applies to both leaf and stem forms.

## GROWTH ON LEAVES

The life history of the alga on leaves differs from that on the branches. If the alga starts growth on the upper surface of the leaf it is at first purely superficial and sometimes remains so. Occasionally it invades some of the epidermal cells and the upper ends of the palisade cells. The latter are stimulated to produce transverse cell walls cutting off their invaded ends from the uninvaded portion. The alga does not make much progress in the upper surface tissues. When the alga makes its initial growth on the under surface of the leaf it enters the intercellular spaces through

the stomata and isolates groups of cells from their water supply thus forming a dead spot. Later the fruiting filaments burst through the epidermal layers on both surfaces.

## GROWTH ON BRANCHES

On the branches in the earlier stages of the disease the algal elements are mostly superficial. They spread out in sheets through the corky strata. At a later stage the algal cells penetrate more deeply and spread out at deeper levels. Meanwhile the outer corky strata, cut off from the water supply by the layers of algal cells, peels off. The peeling off process may go on until the bast layer is exposed. On occasion algal filaments may be found in the medullary rays but usually they do not penetrate beyond the cambial layer. Their presence below the bast seriously interferes with the translocation of sap and causes the starvation of the tissues above the diseased area. The upper portions of branches attacked by Red Rust are frequently leafless and moribund on that account.

When the growth of the infected branch is normal the extension of the algal cells between the layers of living tissue is negligible. Whenever the growth of the host branch is checked unduly the algal cells make further advances. On slow growing banjhi twigs such as those round the edges of a plucked bush the alga is very commonly present within patches of epidermal tissue but they do not as a rule succumb to the attack. More rapidly grown branches however are more susceptible to serious damage should the growth be checked unduly. Seedlings and young plants generally are more readily influenced by temporary changes in conditions of growth than plants that have a well established root system. At the same time the growth is more succulent and the tissues less resistant to penetration on such plants. In consequence they are particularly liable to suffer damage from this disease.

## THE FRUCTIFICATION

Filaments of algal cells project from the exposed surface of the disc or force their way through the outer layers of cork cells on the host plant. Some of these projecting filaments are sterile hairs, but at times, particularly during May, June and July, many of them produce groups of ovoid receptacles. The contents of these divide up into spores. These spores are provided with two hairs which enable them to swim about in water.

Diagram of a cross section of a tea stem (about 2 years old) showing the formation of new cork below the portion damaged by the Red Rust alga. 1. Original cork layer killed by the alga. 2. Cells invaded by the alga. 3. Newly formed cork layer below the damaged tissues.

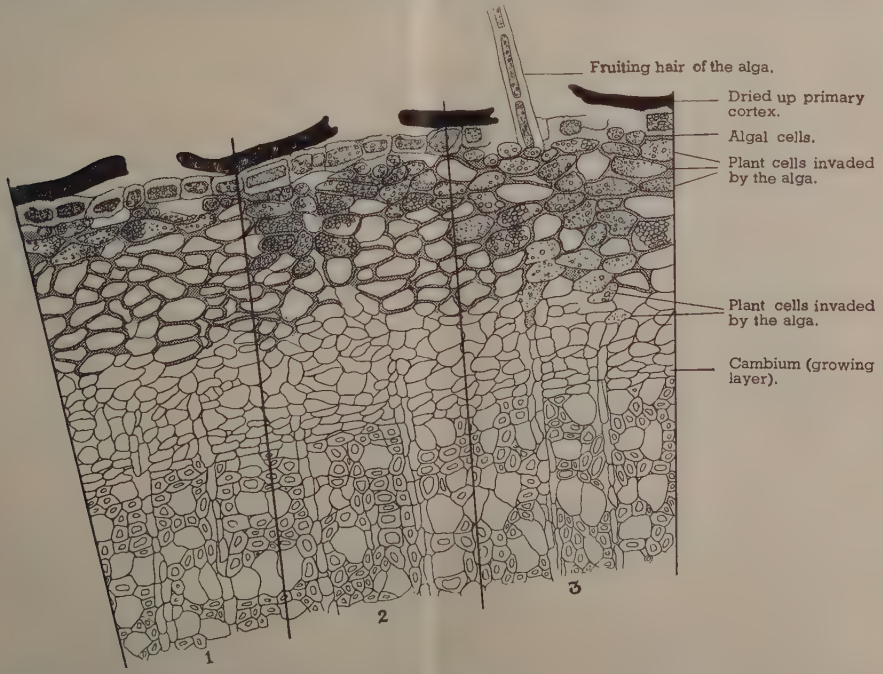



Diagram showing the progressive invasion of the tissues of a one year old tea stem by the Red Rust alga.

Cunningham, who described the alga in 1897 found cysts embedded in the algal elements and suggested that these were a sexual stage. Although very many specimens have been examined at Tocklai no sexual process of reproduction has been observed. Some of the cells however have thicker walls and are larger and rounder than the others, but their contents do not seem to differ from those of other cells.

## THE LICHEN FORM

The alga occasionally lives symbiotically with a fungus forming a lichen. This form is greyish-green and very commonly seen on the upper surfaces of old leaves of any kind growing in places where the air is particularly humid such as in or near heavy jungle. The alga is afforded protection by the fungal filaments, while the fungus obtains carbohydrates by parasitising some of the algal elements. Lichens of many kinds are common on the bark of tea bushes. Some of them, at the higher elevations form thick moss-like layers that have to be scraped off at intervals. There are many algae, other than the Red Rust one, associated with these lichens.

## THE NAME OF THE ALGA

A similar alga was called **Cephaleuros virescens** by Kunze in 1829. The material he examined came from Cuba but none of the specimens were preserved. In 1884 Marshall Ward described an alga which appeared to be identical with **Cephaleuros virescens** described in 1829 by Kunze. In 1897 Cunningham working on specimens of tea branches obtained from Nowgong, Assam, described the alga and identified it as **Cephaleuros virescens,** Kunze. He described the organism very fully in a paper published in the Scientific Memoirs by Medical Officers of the Army in India. Cunningham had previously named the same alga **Mycoidea parasitica,** Cunningham.

In 1889 P. Hariot in a note on the genus **Cephaleuros** considered that **Mycoidea parasitica,** Cunningham, was identical with **Cephaleuros virescens,** Kunze, as described by Marshall Ward. In 1891 Karsten who had made a special study of the family to which the alga belongs refused to accept this and named the alga described by Cunningham as **Cephaleuros mycoidea,** Karst. Massee however,

considered **Cephaleuros virescens,** Kunze, and **Cephaleuros mycoidea,** Karst, to be synonyms. This was also accepted by Delacroix, the eminent French Plant Pathologist. Petch, in his book "The Diseases of the Tea Bush" states that there are undoubtedly two species—**Cephaleuros mycoidea,** Karst, which is purely epiphytic and **Cephaleuros parasiticus,** Karst, which is parasitic. The writer has examined many specimens of both types and has failed to distinguish any significant difference in the fructifications of the alga living as a parasite and that living purely epiphytically. The vegetative parts do certainly differ but this difference may be due solely to the influence of environment. The cysts described by Cunningham in 1897 have been observed fairly frequently but have not been seen to produce spores and modern staining methods have failed to reveal the changes in the cell contents that may be expected were the cysts the result of a sexual process. The writer has adopted the name **Cephaleuros parasiticus,** Karst, for the organism associated with the Red Rust of tea as it seems the more appropriate name. The old specific name **virescens** seems to be singularly inappropriate as it means, making green. The alga concerned is peculiar in that the chloraplasts contain a red pigment instead of the usual green and the general appearance is of redness, not greenness. The generally accepted common name for the disease, Red Rust, is unfortunate as it suggests similarity with the Rust of wheat. The latter disease is caused by an entirely different organism—a fungus not an alga.

The following bibliography may be found useful to future investigators of this alga.

Marshall Ward, "Structure, development and life history of a tropical epiphyllous lichen." "Transactions of the Linnean Society" (1884) Series II, Vol. II, p. 87 with plate.

Cunningham, "On **Mycoidea parasitica**" in "Transactions of the Linnean Society", Series II, Vol. I, p. 301 with plate.

Hariot, "Note sur le genge **Cephaleuros**" in "Journal de Botanique", Vol. III, 1889, pp. 274-284.

Karsten, "Untersuchungen Uber die Familie der Chroolepideen" in "Annales du Jardin Botanique de Buitenzorg", Vol X, 1891, pp. 24-25.

Cunningham, "Bark blight caused by **Cephaleuros virescens,** Kunze" in "Scientific Memoirs by Medical Officers of the Army in India", Part X, 1897, p. 111.

Mann and Hutchinson, "Red Rust", 2nd edition, Indian Tea Association, Bulletin No. 4, 1904.

Delacroix, "Maladies des Plants" Bibliotheque d 'Agriculture Coloniale, pp. 359 *et seq* with plates (1911 edition).

Massee, "A Text Book of Plant Diseases" p. 343.

Butler, "Fungi and Disease in Plants" pp. 413-422 with plates (1918).

Petch, "Diseases of the Tea Bush", pp. 54-56 with plates (1923).

## ALLEVIATION OF DAMAGE ASSOCIATED WITH RED RUST

### The distribution of the disease

The organism associated with Red Rust may be found everywhere in the North-East Indian tea districts at all seasons of the year. The spores are produced in very large numbers and in spite of their small size and delicate structure they are able to withstand desiccation for considerable periods. Their small size renders easy their transport by air over long distances. They are motile and can move about freely in films of moisture. On branches the alga produces layers of cells well protected from adverse conditions by the bark of the host plants. In the epiphytic form it is able to go into partnership with a fungus to form a lichen which is very resistant to climatic changes. Taking all this into consideration it is not surprising that the organism concerned is very widespread and its eradication is quite out of the question. Whatever treatment may be applied there is always an ample supply of spores available to initiate infection. The problem therefore, is how to keep the tea bush in such a condition that it does not suffer damage from infection.

## SUSCEPTIBILITY TO RED RUST DAMAGE PROBABLY ASSOCIATED WITH DEFECTIVE WATER SUPPLY

The Red Rust alga takes water from the tissues it invades. It is provided with means of absorbing light and manufacturing the carbohydrates it requires. The superficial portions of the alga

are probably self-supporting in this respect. The layers of the algal elements embedded in the tissues of the host plant probably obtain most of their requirements by parasitising the host plant. The principal requirement however is water and the presence of the algal elements in the bark of a branch is accompanied by indications of diminished water supply in the portion of the branch above the infected area. When the host plant is functioning normally the water requirements of both itself and the alga are sufficient and the tissues of the host plant beneath the layer of algal elements are not damaged. If however the water supply is impaired the layer of cells beneath the algal elements becomes moribund and a new layer of algal cells is formed adjoining living cells of the host plant. A study of series of microscope sections shows this progressive invasion clearly. It seems therefore probable that susceptibility to damage from Red Rust is largely associated with the water supply to the tissues of the host plant.

Any injury to a branch which impairs the water supply is almost invariably followed by an invasion of Red Rust elements in the young wood above the injury. Red Rust is very commonly found parasitising broken side branches. In this connection it is interesting to note that the removal of a ring of bark does not have this effect so long as the outer portions of the wood are not damaged. This is illustrated by the fact that marcots are not particularly susceptible to injury from Red Rust until they have been severed from the parent plant. Prevention of injury from Red Rust seems therefore to be a matter of ensuring the optimum absorption and transportation of water from the soil to the branches.

## FACTORS CONDUCIVE TO DEFECTIVE WATER SUPPLY

The root system of a tea plant is the only agent for the absorption of soil water. The various factors which prevent the proper functioning of the root system are discussed below.

**Lack of soil moisture** is the most obvious cause of poor absorption. In the case of plants with a good deep root system the ordinary dry conditions in the cold weather do not seriously impair the absorption of the plants' requirements as the deeper portions of the root system are usually in damp soil. Young plants of necessity have a smaller root system and are thus more liable to damage from drought and also from Red Rust. Any restriction of the depth

and extent of the root system, whatever the causes, renders the plants concerned more liable to the damage resulting from the lack of water during periods of dry weather. The problem therefore resolves itself into the amelioration of any conditions which restrict the development or maintenance of a good root system.

**Bad aeration of the soil** is the most frequent cause of poorly developed root systems and observation shows that bad drainage was the most frequent condition associated with bad attacks of Red Rust on mature tea. Bad drainage is not however, the only cause of bad aeration as the nature of the soil in some cases makes aeration difficult. Loss of tilth associated with injudicious cultivation such as constant hoeing in very wet conditions often interferes with the root system of old tea. The physical condition of such soils may often be improved by suitable manures applied over a series of years. Much improvement has been seen where improved drainage, combined with suitable manuring, has been applied. Many sections of old tea that were at one time particularly liable to damage from Red Rust are now in good condition.

**Undue reduction in leaf area** also has an adverse effect on the action of the roots, particularly so when it is followed by severe pruning. The raising of the water from the soil to the branches requires the expenditure of energy. This energy is absorbed from the light by the green portions of the plant. It is stored in the woody portions of the roots in the form of carbohydrates, principally starch. If the leaf area is reduced to such an extent that an insufficient amount of carbohydrates reach the roots, absorption of soil water is reduced. The upper portions of the plant concerned are then affected by the lack of water supply and become more susceptible to damage from Red Rust.

**Damage to the collars of plants** by disease or mechanical injury may cut off supplies of carbohydrates to the roots, thus impairing their function and inducing conditions of drought in the tissues. This is often observed in seedlings and young plants.

## OTHER FACTORS ASSOCIATED WITH RED RUST DAMAGE

**Alkalinity of the soil** has been repeatedly shown to be detrimental to tea, in particular to young plants. Tea plants growing on soil which is insufficiently acid are usually badly attacked by Red Rust.

**Various fungus diseases** particularly those attacking the water absorbing and transporting tissues may often be associated with more or less severe Red Rust damage.

## RECENT OBSERVATIONS ON RED RUST

The increase in the tendency to damage from Red Rust in young plants was noted some time ago and special observations have been made for some years.

**The effect of spraying on Red Rust.**—Observation on the intensity of the Red Rust attack on young tea (Deamoolie Assam Clearance 1935) at Borbhetta, were made in June, July and August 1938. It should be noted that the attack was not very severe at any time.

There are six series of plots treated as follows for three consecutive years.

1. Control—nil.
2. Cowpeas sown at 1½ mds. per acre.—good crop.
3. Matikalai sown at 1½ mds. per acre.—very poor crop.
4. Daincha sown at 1 md. per acre.—good crop.
5. Arhar sown at ½ md. per acre.—good crop.
6. Sulphate of ammonia 200 lbs. per acre.

Each plot was divided into 4 portions which were marked a, b, c and d.

The intensity of the Red Rust attack was noted in the 2nd week of June, and at that time there was no suggestion of difference between the series.

The plots concerned were sprayed with—

a. Perenox 4 oz. per 10 gallons, ·25 per cent.

b. 1 per cent Burgundy mixture with rosin adhesive.

c. Lime sulphur solution 1 in 10 (Jorhat Tea Coy's concentrate).

d. Control.

The intensity of the attack was estimated as follows.

| | |
|---|---|
| No Red Rust visible | = 0 |
| Visible but causing no obvious damage | = 1 |
| Damage caused to some of the branches | = 2 |
| Damage caused to most of the branches | = 3 |

Thus if every bush were attacked but without any apparent damage the actual figure for each spraying series would be 720 and for each manurial series would be 480. From the following tables it may be seen that comparatively little damage was apparent. The following table shows the effects of the spraying. It may be seen that three weeks after spraying the corrected figures show that the 1 per cent Burgundy mixture and the ·25 per cent Perenox gave almost identical results. Lime sulphur solution had significantly less effect but was better than nothing. Eight weeks after spraying the differences were no longer significant.

The figures obtained are given below.

| | Just before spraying. | After spraying. | | Aug. 1st-3rd. |
|---|---|---|---|---|
| | June 10th-11th. | July 4th-5th. | | |
| | Actual. | Actual. | Corrected. | Actual. |
| Perenox ·25 per cent, 4 oz. per 10 gallons ... | 826 | 203 | 195·2 | 282 |
| 1 per cent Burgundy mixture with rosin adhesive ... | 795 | 195 | 194·3 | 270 |
| Lime sulphur solution 1 part 23° Beaume in 10 parts of water ... | 765 | 319 | 325·2 | 309 |
| Control ... | 756 | 360 | 368·3 | 308 |
| Significant difference (P = ·05) ... | None | 45·6 | 42·8 | None |

The following table shows the apparent effect of the various soil treatments. Three weeks after the spraying the Red Rust on the plots on which a good green crop was growing was significantly less. This difference was even greater eight weeks after spraying. It may be mentioned that the green crops afforded a certain amount of shade to the tea plants during the period concerned. This shade was considerably less at the time of the first observation.

| | Just before spraying. | After spraying. | | Aug. 1st-3rd. |
|---|---|---|---|---|
| | June 10th-11th. | July 4th-5th. | | |
| | Actual. | Actual. | Corrected. | Actual. |
| Control ... | 530 | 198 | 197·5 | 239 |
| Cowpeas (good crop) ... | 520 | 149 | 150·8 | 189 |
| Matikalai (very poor crop) ... | 473 | 185 | 197·6 | 243 |
| Daincha (good crop) ... | 493 | 144 | 152·0 | 117 |
| Arhar (good crop) ... | 575 | 170 | 159·2 | 131 |
| 200 lb. Ammonium sulphate per acre ... | 551 | 231 | 225·7 | 250 |
| Sign. difference (P = ·05) ... | None | 37·2 | 35·0 | 37·6 |

Too much reliance should not be placed on the differences associated with the green crops. It has been observed that while in most years the shade afforded by green crops such as Boga medeloa, Arhar and Daincha seems to reduce the tendency to damage from Red Rust, the reverse is sometimes the case when a cold weather drought occurs. The effect of the competition for soil water supplies then becomes apparent. The application of sulphate of ammonia had no significant effect on the Red Rust.

Observations on the intensity of the Red Rust attack on young tea (Deamoolie Assam Clearance 1935) at Borbhetta had previously been made in June, July and August 1938. In 1940 the plots were sprayed on June 3rd-6th in the following way.

a. Perenox ·125 per cent, 2 oz. per 10 gallons.

b. Perenox ·25 per cent, 4 oz. per 10 gallons.

c. Perenox ·5 per cent, 8 oz. per 10 gallons.

d. Control 0 per cent.

Observations on the intensity of attack were made three weeks after spraying. The method of estimating the intensity of the attack was as described above.

The results of our observations following the spraying were as follows.

| Treatment. | Degree of Red Rust infection. | |
|---|---|---|
| Applied June 3-6-1940. | Estimated 1940 3 weeks after spraying. | Estimated May 1941 (One year after spraying). |
| Perenox ·125 per cent, 2 oz. per 10 gallons water | 262 | 353 |
| Perenox ·25 per cent, 4 oz. per 10 gallons water | 277 | 300 |
| Perenox ·5 per cent, 8 oz. per 10 gallons water | 260 | 290 |
| Control 0 per cent | 321 | 440 |
| Significant difference (P = ·05) | 56 | 61 |

There was no significant difference associated with the soil treatments (green manures) up to 1939 on this area.

These observations show that Perenox even as dilute as ·125 per cent has a significant effect on Red Rust not only a few weeks after the application but also during the next season—a year later. As the growth then liable to attack had mostly grown after the spray fluid was applied the residual effect cannot be due to the presence of the spray fluid on the surface of the branches concerned.

Although a concentration of Perenox as low as ·125 per cent has given good results in the above experiment it must be remembered that the application was made in the growing season. For purposes of the experiment it was of course necessary to choose an area that was being attacked. This could not be selected before the fructifications appeared. As stated elsewhere the right time to spray for Red Rust treatment is early in the cold weather although at that time the organism is in a semi-dormant state and thus less susceptible to treatment. Hence ·5 per cent Perenox is suggested for application at that time.

**Estimation of effect of jat and manure.**—Opportunity was also afforded to make observations on the intensity of Red Rust on the light-leaf and dark-leaf manuring plots in the Silbhetta block (1935 Clearance) at Borbhetta. There are altogether 144 plots of 8×12 =96 bushes each under experiment. The two middle rows in

each plot (8 bushes in a row) were examined and the Red Rust estimated in the middle of June in the same manner as in case of Deamoolie plots. These plots were manured with nitrogen, potash and phosphoric acid in varying amounts. The intensity of the Red Rust attack was estimated in the same manner as before. It should be noted that the attack was not severe at any time.

Significant effects were produced by jat and potash.

The relevant figures are given below.

| Jat. | Intensity of attack. |
|---|---|
| Light leafed plants | 1309 |
| Dark leafed plants | 1076 |
| Sign. diff. at P=·05 | 58·7 |

The light leafed tea was distinctly more susceptible to Red Rust attack.

| Potash. | Intensity of attack. |
|---|---|
| Potash nil | 817 |
| Potash 20 lbs. | 814 |
| Potash 60 lbs. | 754 |
| Sign. diff. at P=·05 | 47·9 |

The larger dose of potash was associated with significantly less Red Rust but the difference was too small to be of practical importance. Neither nitrogen nor phosphoric acid applied at the same rates as the potash had any effect on the Red Rust.

## TREATMENT

Spraying with Bordeaux mixture (similar to Burgundy mixture but made with quick-lime instead of soda) was introduced to tea in North-East India with the object of palliating this disease. It was found that applications of 1 per cent Bordeaux mixture made in the cold weather prevented a great deal of the disease.

For very many years it was the custom to dip young plants into Bordeaux mixture at the time of planting out. This was almost invariably done in the case of infills for the specific purpose of

preventing Red Rust attacks. With improved cultural methods the dangers of attack were much reduced and the custom was gradually abandoned. Now-a-days when planting out is almost all being done on old tea soils and the growth of the young plants is not likely to be so vigorous, it would be worth while to reintroduce it, using either 1 per cent Burgundy mixture with rosin adhesive or ½ per cent Perenox. The thorough spraying of young tea with either of the above solutions early in the cold weather each year would also be worth while.

The efficacy of treatment with copper fungicides as a palliative of Red Rust is not in question. It was well established by Mann and Hutchinson in 1904-7. They also found out that spraying at the time the fructifications are visible i.e., early in the growing season is not so effective. It does however save some of the less severely infected twigs. This may be very important in the case of young plants.

Spraying with Burgundy mixture or other suitable copper mixtures kills the alga even when it is within the tissues as the damaged tissues readily absorb copper compounds. It is obvious that the best time to spray tea plants to prevent damage from Red Rust is in the cold weather just after pruning. At that time less fluid will be required to wet all the surfaces and there is less danger of its being washed off by rain before it has had time to penetrate the infected tissues. The application of suitable spray fluids at that time will do much to prevent damage from Red Rust during the somewhat uncertain conditions early in the following season.

The application should be thoroughly done so that the bark of the younger wood is well wetted. In the case of plants under 5 years old, the whole plant should be wetted. It is therefore necessary to use an adhesive in the fluid. 1 per cent Burgundy mixture with rosin adhesive is found satisfactory for this purpose. ½ per cent Perenox is also a good substitute. As the Perenox contains a wetting compound it is unnecessary to add an adhesive to it.

Little damage will result from any infection which may occur in June, July and August until the following March, April and May. Instances have been noted of severe damage occurring in October

and November but these are exceptional and may be associated with exceptional climatic conditions. Spraying early in the growing season may have prevented such damage but it was impossible to estimate the need for this application until the damage had occurred. Although the most satisfactory time for spraying is just after pruning, application made at any time before the beginning of March will be likely to prove satisfactory. Later than this the chances are that it will be too late to prevent serious damage although some of the less seriously attacked stems may be saved.

## SUMMARY

After nearly 30 years of personal observations on this disease the writer believes that the principal factor concerned in susceptibility to damage from Red Rust is water supply. Young plants have not had time to establish a root system sufficiently deep to maintain contact with the layers of sub-soil which contain a more or less permanent supply of moisture. Hence they are more susceptible to the effects of cold weather droughts and the consequent check to growth affords an opportunity for the Red Rust alga to take up a parasitic existence at their expense. In the case of older tea, restriction of the depth of the root system on account of bad drainage or any other factor restricting root growth is the most important condition favouring Red Rust damage. Undue restriction of leaf area caused by injudicious plucking or pruning and consequent lack of reserves is also conducive to Red Rust damage. It should however be noted that on occasion bushes well supplied with reserves of starch have been found suffering from very severe Red Rust attack. In some of these cases the soil was found to be insufficiently acid for the satisfactory growth of tea.

There does not seem to be any evidence of the direct effect of manuring with phosphoric acid and nitrogen on susceptibility to damage from Red Rust. There is some experimental evidence that potash manuring decreases susceptibility to attacks of the blight at Borbhetta. Any manuring which encourages better growth of young plants may palliate damage from the attack indirectly, by improving root growth.

It may be said without fear of contradiction that any set of conditions likely to cause weakness in the plants as a whole or to

individual portions of their frames is likely to favour damage by Red Rust. The improvement of conditions takes time and while that is being brought about it is sometimes desirable to control the effects of the Red Rust invasion by direct action against the organism concerned. To be effective it is necessary to apply such action before the damage has occurred.

## RECOMMENDATIONS

Where local experience suggests that the tea plants on a particular area are likely to suffer damage from Red Rust the following treatment should be applied.

1. Mature tea.— Early in the cold weather the one and two year old wood should be wetted thoroughly with either 1 per cent Burgundy mixture with rosin adhesive or ½ per cent Perenox (½lb. Perenox in 100 lbs. water).

2. Young tea.— Early in the cold weather, plants up to 5 years old should be thoroughly wetted all over with either of the above mentioned spray fluids.

   The stems of seedlings may be dipped in one of the spray fluids at the time of planting out.

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